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Abstract

In spite of the mystique behind a central bank's balance sheet, its resource constraint bounds the dividends it can distribute by the present value of seignorage, which is a modest share of GDP. Moreover, the statutes of the Federal Reserve or the ECB make it difficult for it to redistribute resources across regions. In a simple model of sovereign default, where multiple equilibria arise if debt repudiation lowers fiscal surpluses, the central bank may help to select one equilibrium. The central bank's main lever over fundamentals is to raise inflation, but otherwise the balance sheet gives it little leeway.

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The *New Oxford American Dictionary* defines mystique as "a fascinating aura of mystery, awe, and power surrounding someone or something". This characterization applies to the balance sheet of a central bank. It has fascinating liabilities, dominated by currency and bank reserves, which are legal tender that cannot be converted into anything else than what they already are. There is an aura of mystery around the central bank's accounts, which follow peculiar accounting principles like the Federal Reserve valuing its securities using face value rather than market value, or the large TARGET2 claims from some members of the Eurosystem on the others. The central bank is perceived with awe to have immense power in part because it can fund unlimited purchases of any asset, and it is usually successful at fixing one key price in an economy, whether it is the short-term rate or the exchange rate. Some even argue that a country with its own central bank can never go through a sovereign default, because it can always pay debts with newly-created reserves.

This paper works through the resource constraint of a central bank to remove some of this mystique. From an accounting perspective, it is difficult to keep track of the value of the assets and liabilities in a central bank's balance sheet. Not only are these assets and liabilities peculiar, but there are also no accounting standards that naturally apply to a central bank, which is neither a private corporation nor a conventional government agency. Yet, from an economic perspective, a central bank is an agent with limited resources. Keeping track of the sources and uses of these resources reveals what the central bank can and cannot achieve.

The analysis applies to a generic central bank in an advanced economy, but for concreteness I will refer to it as the Eurosystem or ECB, and to the euro as the currency. Each section poses a question that is inspired by discussions of the ECB's role during the recent crisis. The main conclusion is that the central bank's main power is to raise its inflation target, but otherwise its balance sheet gives it little leeway to pursue other goals.

1 Does a central bank have unlimited resources?

A central bank has two different types of liabilities. One of them is special because it gives its holders a return below the market return, which I simplify to zero. There is demand for these assets because they provide some other service, perhaps as a means of payment or perhaps as safe collateral for other financial transactions. I use h_t to denote the total amount in euros of these special assets. In the Euro-area, their main component are the banknotes in circulation.

The other type of liability is just like any other financial asset and must therefore pay the safe market return. One example are the trillions of dollars of excess overnight reserves in the United States during the recent financial crisis. In some countries, the central bank issues bonds of longer maturity and finds itself paying a market return. For the Eurosystem, these liabilities also include required reserves, which pay the short-term overnight interest rate by the statutes of the ECB. I denote their total amount by v_t, and the safe promised return they pay between t and $t+1$ is i_t.

On the side of assets, most of the times central banks hold a limited set of treasury securities plus some foreign exchange reserves. During a financial crisis, the size and scope of their assets significantly enlarges. Reis (2009) discussed the unconventional assets the Federal Reserve chose to hold in 2007-09, while Reis (2011) solved for the optimal security holdings when financial markets are segmented. For the Eurosystem, in 2012 these assets include the many securities accepted for collateral in the refinancing operations of the ECB, and especially the government bonds of the different countries of the Euro-area. I assume there are J such assets, each earning a potentially stochastic return i^j_{t+1}, and the central bank holds a^j_t euros of each asset for a total amount $a_t = \sum_j a^j_t$. Among these J assets, some may be short and others long-lived, some may be bonds and others loans, some may be denominated in domestic and others in foreign currency.

Finally, the central bank pays a dividend to the treasury, which I denote by d_t in real terms. In most developed countries, this dividend is equal to net income, but there is some variation in how this is calculated, especially on whether to use nominal or real returns, or whether to mark assets to market or not. Hall and Reis (2012) discuss how different rules affect the solvency of the central bank and its independence from fiscal authorities. Here, I study how large d_t can be as a measure of the real resources generated by the central bank.

Combining all of these elements, the resource constraint of the central bank is:

$$h_{t+1} + v_{t+1} = h_t + (1 + i_t)v_t + a_{t+1} - \sum_{j=1}^{J}(1 + i^j_{t+1})a^j_t + p_{t+1}d_{t+1} \tag{1}$$

at all dates, where p_t is the price level. This law of motion for the total liabilities of the central bank shows that it must raise new funds, $h_{t+1} + v_{t+1}$, in order to: (i) pay for the outstanding special liabilities and interest-bearing liabilities, $h_t + (1 + i_t)v_t$, (ii) expand the balance sheet by buying new assets, a_{t+1} in excess of the gross return on last period's assets $\sum_{j=1}^{J}(1 + i^j_{t+1})a^j_t$, and (iii) pay dividends of $p_{t+1}d_{t+1}$ euros.

What makes the v_{t+1} liabilities safe is the central bank standing ready to exchange them on par for currency, which is part of h_{t+1}. This commitment also implies that the central bank does not independently choose the composition of its liabilities. If agents suddenly desire to exchange v_{t+1} for h_{t+1} or vice-versa, the central bank must accommodate this desire. There is a common misconception that the central bank can just print banknotes, raise h_{t+1}, and therefore fund an unlimited amount of resources paid out, d_{t+1}. This is not correct, because h_{t+1} is not an exogenous variable. Rather, it is endogenously determined because of the commitment to keep h_{t+1} on par with v_{t+1}.

The central bank affects h_{t+1} but through interest rates and inflation. Because monetary policy affects the safe nominal interest rate, i_t, it will affect the relative demand for the liability that pays interest, v_t, and the one that does not, h_t. Changes in interest rates come with changes in expected inflation though, so the ability of the central bank to collect interest is closely related to how closely it sticks to its inflation target.

Moreover, there is a limit to the resources the central bank can generate in terms of their real purchasing power. To see this, let $s_{t+1} = (h_{t+1} - h_t)/p_{t+1}$ stand for the real seignorage resources. Their value is the sum of the payoffs weighted by their relative value in different states of the world. This is determined by the real stochastic discount factor (SDF) between dates t and $t+1$, denoted by $m_{t,t+1}$. To value payoffs at further dates, the SDF is $m_{t,T} = \prod_{\tau=t+1}^{T} m_{\tau-1,\tau}$. The value of asset holdings then satisfies the condition:

$$a_t = \mathbb{E}_t \left[\frac{m_{t,t+1} p_t}{p_{t+1}} \sum_{j=1}^{J} (1 + i_{t+1}^j) a_t^j \right], \tag{2}$$

where $\mathbb{E}$ is the expectations operator. In turn, the safe rate of return is the inverse of the value of an asset that pays off €1 for sure next period:

$$\frac{1}{1+i_t} = \mathbb{E}_t \left(\frac{m_{t,t+1} p_t}{p_{t+1}} \right). \tag{3}$$

Note that both i_t and i_{t+1}^j refer to payments made at $t+1$, but they have different time-subscripts because they are known at different dates.

Multiplying by the SDF and taking expectations on both sides of equation (1) gives the expected value of the resources generated by the central bank, where a hat denotes the real value of asset holdings:

$$\mathbb{E}_t \left(m_{t,t+1} d_{t+1} \right) = \mathbb{E}_t (m_{t,t+1} s_{t+1}) + (\hat{a}_t - \hat{v}_t) - \mathbb{E}_t \left[m_{t,t+1} \left(\hat{a}_{t+1} - \hat{v}_{t+1} \right) \right]. \tag{4}$$

This expression shows that the central bank has two sources of resources. The first source is expected seignorage generated by expanding the special liabilities of the central bank. Because the central bank can use these funds to invest in assets that earn market interest rates, it can create resources. From another perspective, these liabilities are special because they provide a service to economy agents, for which the central bank will collect some revenue.

There is a strict limit to this revenue. The central bank is committed to satisfy the demand for these special liabilities by exchanging them on par with its other liabilities. There are many models of this demand, from the classic model of Cagan (1956) to the modern approach of Lagos and Wright (2005). All of them predict that velocity, the ratio of nominal expenditure to h_t, increases with the nominal interest rate. Letting $L(i)$ be the inverse of velocity, so $L'(.) \leq 0$, seignorage revenue as a ratio of expenditures is:

$$L(i_{t+1}) - \frac{L(i_t)}{1 + g_{t+1}}, \tag{5}$$

where g_{t+1} is the growth rate of nominal expenditures. There are two relevant properties of the function defined by this expression. First, the central bank can only increase it by generating higher nominal interest rates or higher nominal expenditure growth. This is only possible in a sustained way with higher inflation. Second, countless theoretical and empirical studies have found that there is a maximum to this inflation tax. Over the past decade, the average value of seignorage in the Euro-area has been 0.6% of GDP and it has never been above 0.9%. Hilscher, Raviv and Reis (2013) estimate that the theoretical maximum is a small multiple of the average. The central bank's ability to generate seignorage revenues is limited and depends on tolerating higher inflation.

The second and third terms on the right-hand side of equation (4) show that the central bank can also fund an increase in dividends by either selling assets or increasing its market liabilities. When a central bank performs an open market operation, this does not happen. It purchases assets from financial institutions by crediting their accounts at the central bank, so the procedure by which the central bank raises a_{t+1} involves an automatic expansion in

v_{t+1}. The value of $a_{t+1} - v_{t+1}$ is unchanged.

2 Can the central bank be a source of significant revenues?

Besides open-market operations, there is a long list of unconventional policies that central banks can pursue with their balance sheet. In terms of the resource constraint, there are many possible combinations of changes in asset holdings and liabilities that can temporarily raise dividends. It is more useful to focus on the total amount of resources the central bank can generate over its potentially infinite horizon.

Let D_t be the expected present value of future dividends, defined by the recursion:

$$D_t = \mathbb{E}_t \left[m_{t,t+1} \left(d_{t+1} + D_{t+1} \right) \right] \tag{6}$$

and likewise for the expected present value of future seignorage S_t. Then, iterating the resource constraint in equation (4) forward to infinity gives:

$$D_t = S_t + \hat{a}_t - \hat{v}_t - \lim_{T \to \infty} \mathbb{E}_t \left[m_{t,T} \left(\hat{a}_T - \hat{v}_T \right) \right]. \tag{7}$$

The last term on the right-hand side shows that an increase in dividends funded by extra liabilities must be sustained by higher liabilities forever. For this to work, the private sector must be willing to lend these resources to the central bank. There is controversy on whether there is a bubble on the special liabilities, h_t, or not. The v_t though are, by definition, central bank liabilities which private agents do not value beyond their return. The central bank should not be able to run a Ponzi scheme on these liabilities because no private agent would accept to be on the other side. Keeping fixed S_t, the liabilities of the central bank must be backed by its assets a_t, so this no-Ponzi scheme condition is that the last term in equation (7) is non-negative.

This gives an upper bound on the resources the central bank can generate:

$$D_t \leq S_t + \hat{a}_t - \hat{v}_t. \tag{8}$$

The previous section discussed why seignorage revenues are bounded above. In turn, $a_t - v_t$ is an initial condition inherited by the central bank. Hilscher, Raviv and Reis (2013) empirically estimate this upper bound finding modest values. Hall and Reis (2012) show that if the central bank follows a real mark-to-market rule in calculating its net income and pays it all every period, then $a_t - v_t$ is constant over time, so the central bank budget constraint reduces to paying all of its seignorage as dividends.

3 Can the central bank redistribute resources across regions?

The Eurosystem pays dividends to many fiscal authorities. Equation (7) constrains the total amount of dividends it can pay, but not how they are distributed. The central bank could, in principle, send the whole of D_t to just one of its member states. For a small European country, this could be well above 100% of its GDP.

However, almost all central banks have very strict rules forbidding these redistributions. In the United States, the Federal Reserve can only distribute dividends to the federal treasury, not to the state treasuries. In the Euro-area, the Eurosystem's dividends are distributed according to a strict key that equally weights the country's share in the total population and GDP of the European Union. The central bank has no discretion on how to distribute D_t.

The central bank could redistribute resources in an alternative way. While keeping $a_t - v_t$

unchanged, the central bank could hold more assets issued by one region and fewer assets from the remaining regions. Likewise, it could borrow less from one region and borrow more from others. Either of these actions would effectively lend on net to that region, while borrowing from the rest. Because the no-Ponzi scheme condition applies only to the central bank's total borrowing, in principle it could do this forever.

Again though, this economically feasible operation is ruled out by the statutes of most central banks. The Federal Reserve can only hold securities that are not federally-issued or federally-backed in temporary and exceptional circumstances. In the Eurosystem, when one financial institution moves its deposits from the central bank of one country to another, the liabilities to the private sector of the first central bank fall, while the liabilities of the second central bank rise. But, via the TARGET2 system, this transaction is recorded in the Eurosystem as a liability of the first country to the second. The total liabilities v_t of each country are unchanged (see Whelan, 2012 for a step-by-step explanation of TARGET2.)

Moreover, in the refinancing operations that account for most of the changes in its assets, the ECB uses repo operations accepting any collateral from its acceptable list. Therefore, it effectively does not control the composition of a_t. If many borrowers appear at the ECB's auctions offering as collateral securities from only one country, the composition of the ECB's assets will shift towards that country, and the ECB can do nothing to stop it.

If the sovereign states that own the central bank wish to use its balance sheet to redistribute resources, they can. But, in its normal operations, the members of the Eurosystem by themselves cannot control the composition of v_t or a_t, so they cannot redistribute resources across regions.

4 Can the central bank peg sovereign spreads?

During the financial crisis, the ECB went beyond its normal operations. Through its Securities Market Program, the ECB bought sovereign bonds issued by some of the countries in the euro-area. The effectiveness of these interventions is often judged in terms of their effect on sovereign bond yields (European Central Bank, 2011).

Evidence and theory show that two countries that have their own currency can control the spread between their nominal interest rates. Less appreciated is that, in principle, the central bank can also peg the sovereign spread between two regions that share the same currency. Imagine the central bank announces the following standing facility: it will stand ready to buy and sell one sovereign bond in exchange for the other sovereign bond at a target spread. The central bank can back this facility by raising or lowering its liabilities as is necessary. To ensure no arbitrage, the market prices must move to this target spread.

Even if the central bank can do it, pegging sovereign spreads comes with several unsavory implications. Assume that the two sovereign bonds have a maturity of one period. One of the bonds, of a center country, sells for $1/(1+i_t)$ and pays off €1 for sure at $t+1$. The other bond, of a periphery country, sells for $1/y_t$ where y_t is its promised yield, but can either pay €1 next period, or instead $c \leq 1$ to its private holders. The central bank wants to target a value for the periphery yield of y^* that is close to the yield on the center bond $1 + i_t$.

At date t, the nominal risk-neutral probability that the bond does not pay in full is π. The central bank holds $b_t^e \geq 0$ units of the periphery bond, while the private sector holds $b_t^p \geq 0$ units. I forbid short-selling, as often happens during financial crises. All agents trade in the same market, so the private sector will force the following arbitrage condition:

$$y_t \leq \frac{1 + i_t}{1 - \pi + \pi c} \quad \text{and} \quad b_t^p \geq 0, \tag{9}$$

with at least one equality.

The expression $1 - \pi + \pi c$ is smaller than 1 so the periphery bond must promise a higher yield than the center bond, given the risk of default. If the target yield y^* enforced by the central banks's standing facility is below this premium, then the private sector refuses to hold any of the periphery bonds. All private investors appear at the central bank's facility program selling their bonds at the price $1/y^*$, which is higher than what they think the bonds are worth. The central bank's holdings b_t^e rise to absorb the whole supply of the periphery bond. While the central bank can do this, and so peg a yield spread, it would likely be weary of becoming the sole market creditor of a region. Beyond its implications for the central bank's portfolio, this policy would also be an example of the redistributive policies discussed in section 3. Buying and holding all of the periphery bonds forever would require holding fewer bonds from the center, effectively redistributing resources from the latter to the former.

Expression (9) shows that another way to lower the yield would be to lower π. Recall that π is the risk-neutral probability, so it is the product of the objective probability, the SDF, the nominal return, and the inverse of inflation, all in the state when the bonds does not pay. If the central bank could lower the SDF in the default state of the world, it would lower π and so it could lower the yield, because it would make euros in the default state become less valuable to private agents. Under the special assumptions of consumption-based asset pricing with logarithmic time-separable utility in consumption, then π is inversely proportional to expenditure growth, $1 + g_{t+1}$, in the default state. The central bank could target a higher growth rate of nominal income when there is a default, but this stimulus would likely come with higher inflation. This policy works as much by making the periphery bonds more attractive to private agents, as it does by making the center bonds less attractive.

This leaves on way to target a yield y^*, to target a payment in the default state, c^*, that is close to 1. To evaluate this possibility, the next section introduces a simple model of sovereign default.

5 Can the central bank prevent sovereign defaults?

The model rests on two pillars. The first is the budget constraint of the fiscal authorities in the periphery. To simplify, assume that all uncertainty regarding defaults is resolved once $t+1$ arrives. That is, from $t+1$ onwards, the government bonds always pay in full so their yield is the safe interest rate. In the default state of the world, the budget constraint is:

$$cb_t^p + c^e b_t^e = p_{t+1} \left(\delta d_{t+1} + f_{t+1} \right) + \frac{b_{t+1}^p + b_{t+1}^e}{1 + i_{t+1}}. \tag{10}$$

On the left-hand side are the payments on the bonds outstanding from last period. I allow for the payment to the central bank c^e to be different from what is paid on the market c. In the first renegotiation of Greek debt, the ECB was senior relative to the private sector. On the right-hand side are the government revenues: (i) the fixed share δ of the central bank's dividends due to this country, (ii) its real fiscal primary surplus f_{t+1}, and (iii) the revenue from selling new bonds.

Iterating this equation forward, and not allowing the fiscal authority to run a Ponzi scheme with its private creditors, the intertemporal budget constraint of the periphery fiscal authority is:

$$\frac{cb_t^p}{p_{t+1}} = f_{t+1} + F_{t+1} + \delta \left(d_{t+1} + D_{t+1} \right) - \frac{c^e b_t^e}{p_{t+1}} + \lim_{T \to \infty} \left(m_{t+1,T+1} \frac{b_T^e}{p_{T+1}} \right), \tag{11}$$

where F_{t+1} is the expected present value of future primary surpluses. This is the equilibrium equation that pins down c as a function of real fiscal surpluses and other variables under the control of the central bank.

The second pillar describes how fiscal surpluses are determined. The crucial assumption is that $f_{t+1} + F_{t+1} = \Phi(c)$ where $\Phi(.)$ is a weakly increasing function. Brunnermeier et al. (2011) argue that at the center of the European debt crisis has been a diabolic loop caused by banks holding too much of their home country's debt. A sovereign default makes domestic banks insolvent and causes a domestic financial crisis, which lowers tax revenues if it causes a recession, and raises public spending if it leads to a bailout of the financial sector. I will also assume that $\Phi(.)$ is concave: the lower is the repayment on the sovereign bonds, the greater is the damage done to the financial system and the larger the resulting fall in the fiscal surplus.

To analyze the model, start with the case where the central bank is not an active player. This is the case when it keeps the price level on a target that I normalize to 1, when there is no seignorage revenue to distribute, and when the central banks does not hold any of the country's bonds. The equilibrium condition for c in this case becomes:

$$cb_{t+1}^{p} = \Phi(c) \tag{12}$$

and is depicted in figure 1. The left-hand side of the equation gives the fiscal *needs* line, while the right-hand side gives the *means* curve. I drew the figure assuming that the periphery is going through a fiscal crisis, $\Phi(1) < b_t^p$, so full repayment is not feasible using solely fiscal revenues, but this is not essential to the discussion that follows. More important is the sign of $\Phi(0)$, the fiscal surpluses if there is 100% debt repudiation.

If the diabolic loop is weak, so there is a positive fiscal surplus with full repudiation, $\Phi(0) > 0$, then there is a unique equilibrium, depicted on the top panel. The periphery bond almost pays in full. If instead the government default has a large impact on the financial sector and on fiscal surpluses, so that $\Phi(0) < 0$, there is a second equilibrium, depicted on the bottom panel. A severe debt crisis, with low c and high sovereign yields, is possible because it creates the fiscal shortfall that will confirm the large repudiation.

This model of multiple equilibria is different, but related to, the classic model in Calvo (1988) and the recent work by Corsetti and Dedola (2012). There, the fiscal authority is

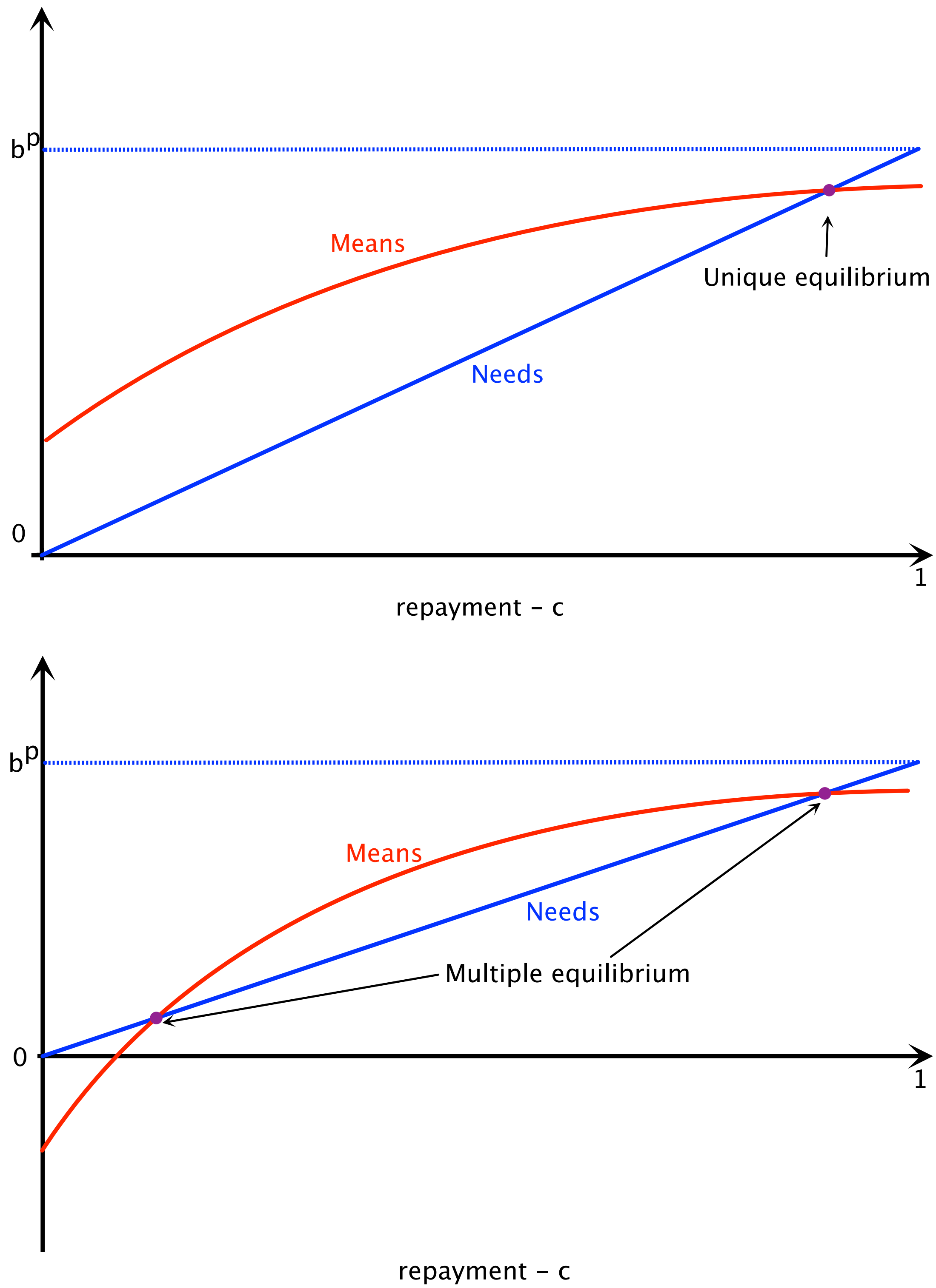

Figure 1: Equilibrium Debt Repudiation

time inconsistent because ex ante it wants to commit to pay the debt in full, to lower the yield on debt and so the repayment that is due, but ex post it wants to repudiate the debt in order to avoid costly increases in fiscal surpluses F_t. In the model above, the fiscal authority always wants to pay its debt but it cannot raise the fiscal surplus. In Jeanne (2012) and Gourinchas and Jeanne (2012), the multiplicity arises because of roll-over risk on long-term debt, whereas in the model above, all of the debt matures after one period. My model is closer to matching the verbal description of the European debt crisis in De Grauwe (2011).

Introduce now the central bank by going back to the general model in equation (11) to see whether it has the tools to raise the equilibrium debt repayment, c. The first action it could take to ameliorate the situation of the peripheral fiscal authority would be to raise fiscal surpluses, $f_{t+1} + F_{t+1}$, directly. This would shift the means curve upwards and could potentially eliminate the bad equilibrium. By stimulating economic activity, central banks are able to raise tax collection and lower benefits spending, but this would typically come with higher inflation.

Raising inflation would also shift the means curve upwards by raising the seignorage that is distributed to the fiscal authorities. If $\delta(d_{t+1} + D_{t+1}) + \Phi(0) > 0$, it could eliminate the bad equilibrium. This mechanism is emphasized in Gourinchas and Jeanne (2012), and it involves a trade-off between eliminating default risk at the expense of inflation risk. As I argued in section 1, there is an upper bound to how much seignorage the ECB can generate. Moreover, the strict Eurosystem rules fix the share of these dividends that can be sent to countries in crisis.

Higher prices would also rotate the needs curve rightwards through a second mechanism. Higher prices erode the real value of debt. This can never eliminate the bad equilibrium, but it can raise repayment in the good equilibrium all the way to 1. There is no limit to the size of this effect, although the increase in prices must be unexpected, for otherwise its effect would be neutralized by higher yields paid when selling the debt.

The central bank could also increase the share of the stock of sovereign debt it holds, raising b_t^e and lowering b_t^p, to then write the debt off by lowering c^e. Alternatively, the central bank could take the other side of a Ponzi scheme run by the government, raising b_T^e. Either of these actions involves a redistribution from the other regions, and so it is subject to the limitations discussed in section 3.

While all of these fundamental policies may have limited scope, if there is multiple equilibria, the central bank can perform another role. It can act as a coordinating device that steers the economy to the high-repayment equilibrium. With its deep pockets and hard-earned credibility, the central bank may well be the natural government agency to perform this role. Designing a policy that robustly achieves this goal requires carefully considering what information to reveal, how transparent to be, and how agents learn about the central bank's intentions (see Morris and Shin, 1998, and the large literature that followed). Realistically, the central bank may only be able to gain some time.

6 The central bank's lever: Raising the inflation target.

Most of the results in this paper have relied on accounting relations and on ruling out arbitrage possibilities so that there exists a stochastic discount factor. I considered several different policy interventions by the central bank that could alleviate sovereign debt problems. For the most part, the answers were negative. The reality of the resource constraint that every central bank faces, and the statutes of the ECB when it comes to redistributions, either rule out or severely limit most fundamental policies that could generate resources. The most promising role for the central bank may be as selecting the best of multiple equilibria, even if only temporarily.

There is an alternative policy, which has appeared in all of the sections so far: to allow inflation to rise above target. Higher inflation would raise seignorage revenues, part of which would be distributed to the region in difficulties. Higher inflation would possibly raise nominal GDP growth which might raise fiscal surpluses and lower asset values if there is a default. Higher inflation would erode the value of the nominal debt, making full repayment more likely. Ultimately, this is the most effective lever at the disposal of a central bank to generate resources. It also makes clear that, once the mystique of the balance sheet is taken away, the choice facing a central bank during a crisis is a familiar one: to inflate or not.

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